

IN THE UNITED STATES PATENT OFFICE

Honorable Commissioner of Patents  
Washington, D.C.

Re: Applicant: JEROME H. LEIBLISON

Ser. No: 449,874 6/16/54

Filed: July 28, 1954

For: AUTOMATIC PRODUCTION  
SYSTEM

50445  
33.00 10/17/61 11/3/61  
RECEIVED 10/17/61 11/3/61  
BY MAIL BY TRACER FROM  
TO ~~PRINTED~~ 24.00-320  
Ady. No. 111-62 1.00 3.22 Div. 4  
8.00 3.26

October 13, 1961

Dear Sir:

In the above identified application, it is desired to  
file a divisional application under Rule 147.

Accordingly, please prepare a certified copy of the  
prints of  
original application, as filed, and prepare and mount those seven  
drawings originally filed which pertain to the elected invention,  
e.g. all original drawings with the exception of those containing  
Figs. 21-26, Figs. 27-29 and Fig. 25' and not including the  
last 3 sheets of drawings submitted with paper # 16.

A check for \$ 70.00 is enclosed herewith which is believed  
to more than apply cover fees for the above and the filing fee.

There is filed herewith an amendment cancelling all the  
claims not pertaining to the elected invention e.g. Group I  
specified on pages 1 and 3 of paper #3 of the parent case.

It is applicant's understanding that the filing date  
of the divisional application will be that on which this paper  
is received.

It is also requested that a print be made of the page  
containing claim 25 of the original application and the drawing  
illustrating Figs. 22 and 23 and that these and all future  
correspondences be mailed to applicant at: 88 Garfield Avenue  
Metuchen, New Jersey.

Respectfully submitted,  
Jerome H. Leiblison  
Applicant



ICAR 449874 Lur Olson 11/37  
72 Precool Av Staten Island N.Y.

The conventional multiple machine set-up or transfer machine is designed to perform specific operations on a single product. It is inflexible and quite often not capable of working on any product or item other than that which it is designed for. If changes in set-up can be made, they are costly as they require considerable labor, tedious adjustments and sometimes tearing down and rebuilding the machines or parts thereof. This is due to the fact that the transfer machine involves a rigid arrangement of power tools which are aligned with a work carrying conveyor. As the work passes along the conveyor it is grasped at each station and positioned respective to said machines by handling fixtures which are designed specifically for the particular work. At each machine, the work is operated upon by a movement of the cutting tool which is determined by mechanical camming, linkages, etc., inherent in the machine set-up. As such, the set-up is inflexible and the machine may be economically employed only where mass production of a single item or product is employed.

The difference between my system and the conventional automatic production or transfer machines is that I attain a high degree of flexibility by providing a series of work holding units, either self-propelled or moved on a conveyor, each of which is supplied with predetermined means for selecting one or more of a variety of machines to perform an operation on work held therein, and each of which is supplied with a simple command system directing the path of travel of said unit and said machine operations in correct sequence. As such, my invention permits a variety of different products to be operated upon without changes in the set-up of the basic machines. My systems are ideal for the job shop receiving orders for the quantity production of various items, and for the manufacturer who has a continual flow of a number of items and is constantly introducing new items. By the use of standard memory recording devices, punched cards and tapes, magnetic tapes, printed circuits, sequential switching, etc., I am able to change the command requirements for any particular operation or operations on a particular product in the simplest and quickest manners. In my system, I provide a command device with each work holding unit directing movement of the product and (or) the machine tool. Each machine therefore remains almost as flexible as if it were attended by an operator. In other systems hereinafter presented I provide simplified automatic handling of work in process in combination with station and position detection, and initiating devices and quickly programmable predetermining computers which permit highly flexible automation at low cost.

S P E C I F I C A T I O N

It is a general object of this invention to greatly improve and lower the cost of automatic production and automation set-ups.

It is another prime object of this invention to provide new automatic production systems which are extremely versatile in that a variety of different products or work pieces may be handled, one after the other if necessary, and be operated on to completion without manual changes or alterations in the production machine or conveying set-up.

Still another prime object is to provide new and improved means of automatic production whereby all work in process transports, machine operations thereon, inspections, assemblies, etc. are done automatically and under the control of preset time-sequence computers.

It is a fourth prime object of this invention to provide new and improved means of automatic product handling and transporting whereby the need of manual attendance or direction is eliminated.

A fifth object of this invention is to provide new and improved automatic devices for moving work in process to any point in a given volume and at the same time provide sufficient support to said devices for said work to be operated on by machinery.

A sixth object of this invention is to provide new and improved automatic means of moving work in process by a unit conveyorized carrier having means to move or direct movement of itself, the work, machine and tool to perform operations thereon at each of said machines.

A seventh object is to provide new and improved means of automatic production whereby the product is always referenced while in process to a base known to a command system associated with a device conveying the product and (or) to production machines working on said product.

It is an eighth object of this invention to provide automatic production devices and components which are not only flexibly applicable to a variety of operations but are adaptable to standard conveying equipment and machinery.

It is a ninth object of this invention to provide new automatic production conveying systems and devices which are so flexible that most any product in certain size and weight range may be operated upon by any machine accessible to said conveying system.

A tenth object of this invention is to provide command operated automatic production systems with means permitting predetermined, yet easily adjustable, sequential operations to be performed in said system within the realm of said command sequences.

An eleventh object is to provide new and rapid means for changing command recordings utilized in command computers for automatic production.

A twelfth object is to provide new and improved automatic production devices driven by command computers which also control inspection devices having feedback provision, thereby greatly improving the precision of such devices.

A thirteenth object is to provide new and improved computers to be utilized in automatic production machines and systems.

A fourteenth object is to provide devices and systems for automatically and rapidly handling work in process, finished goods, or materials to and from a storage area with equipment which is low in cost, simple to operate, easy to maintain and adaptable to a variety of products and operations.

A fifteenth object is to provide improved means for automatically locating reference points in an automatic conveying system without the necessity of physical contact between the conveyor travelling unit and the conveyor trackway at said reference points.

A sixteenth object is to provide automatic production systems which may be used to perform the function of the conventional automatic production or transfer machine yet is more flexible and more easily altered and adjusted.

Fig. 1 is a plan view showing a part of a typical automatic production line of this invention and individual work carrying units situated at spaced intervals along said line.

Fig. 2 is a partially crosssectioned end view of a monorail travelling work carrying unit a number of which comprise the means of transporting work in process to preselected stations and machines such as those of Fig. 1.

Fig. 3 is a partially crosssectioned side view of the monorail track and conveyor of Fig. 2. Fig. 3', a modified section of Fig. 2.

Fig. 4 is a partially crosssectioned end view of a bi-rail conveyor unit which is a modification of the unit of Fig. 2 and 3.

Fig. 5 is a partially crosssectioned end view of the conveyor unit of Figs. 2 and 3 showing an overhead monorail mounting showing means for station identification and locking said unit respective to said monorail when so identified.

Fig. 6 is a partially crosssectioned side view of Fig. 5.

Fig. 7 is a partial isometric view of part of the conveyor unit of Figs. 2 and 3 showing photoclectric means of identifying a station or position on said overhead trackway.

Fig. 8 is a partial isometric view of the lower section of an overhead driven unit conveyor work holding assembly at a work station or machine showing another means of identifying said machine by photoclectric means.

Fig. 9 is a partially crosssectioned end view of the conveyor unit of Fig. 4 showing modifications in the design of the conveyor and in the mounting of the overhead trackway.

Fig. 10 is an end view of still another modification of the conveyor, trackway and mounting of the device of Figs. 1 and 2.

Fig. 11 shows by an end view, a modified conveyor unit work carrier at a work station showing lateral supporting means employable during operations on the work hold therebys.

isometric [redacted] and an end view of an aligning and supporting device shown in FIG. 11.

FIG. 13 is a partial end view of a work conveyor unit of the invention at a machine tool showing another means of engaging and supporting the unit during machining operation of the work held thereby.

FIG. 14 is a partially crosssectioned, partial end view of an automatic machine tool bed or work platform and work conveyor unit platform showing means electrically coupling the two together.

FIG. 15 is a partially crosssectioned partial end view of the units of FIG. 14 showing limit switch and solenoid operated switch control means between the two.

FIG. 16 is a partially crosssectioned, partial end view of a monorail work conveyor unit at a machine tool showing modified work clamping means.

FIG. 17 is a partially crosssectioned, partial end view of a machine tool base or platform with the conveyor units of this invention thereon showing coolant flow and lubricating means associated with machining on work held thereby.

FIG. 18 is a partially crosssectioned, partial end view of a modified work carrier unit riding on a continuously moving belt type conveyor showing also station selection and station handling and clamping devices associated therewith.

FIG. 19 is an isometric view of a modification of FIG. 18.

FIG. 20 is a partially sectioned, partial isometric view of command computer which may be applicable to control the motions of the aforescribed devices.

FIG. 21 is a diagrammatic view of the device of FIG. 20 in circuit with some of the aforescribed components showing also inspection means which may be associated therewith.

By utilizing the devices and systems hereinafter described I am able to provide systems of automatic manufacture of the following nature. All involve an array of machine tools, assembly machines, inspection and finishing devices, etc. which are positioned flanking a conveyor line for moving the work.

(1) A system whereby a self contained work holding fixture is self propelled and (a) moves the work to a series of stations or machines preselected thereby, (b) automatically prepositions or zeros the work respective to each machine,

(c) commands starting of the machine or machine tool, (d) automatically moves the work respective to the tool during the operations by command, (e) automatically removes the work when the tool has finished its operation thereon and (f) moves it on to the next predetermined station.

(2) A system whereby a self contained work holding fixture is self propelled and (a) moves the work to a series of stations or machines, (b) automatically prepositions or zeros the work or work fixture respective to each machine, (c) commands clamping or holding of the work and (or) work holding fixture at said machine, (d) commands starting of the machine or machine tool, (e) commands movement of the machine or machine tool respective to the work, (f) commands stopping of the machine, (g) commands unclamping or holding of the work and (or) work fixture when said commanded operations are completed, (h) automatically removes the work from the machine and (i) moves it on to the next preselected station.

(3) A system whereby a self contained work holding unit or fixture is self propelled and (a) moves the work to a series of stations or machines preselected thereby, (b) is automatically stopped and zeroed at each preselected machine, (c) is automatically supported for machining or commands support upon stopping, (d) commands movement of the machine or machine tool respective to the work and operation of said tool thereon, (e) commands stopping and withdrawal of said machine tool therefrom and (f) moves the work on to the next preselected station.

(4) A system whereby a self contained work holding unit or fixture is moved on a powered conveyor line and is provided with means for (a) preselecting a series of machines along said line and (b) commanding or otherwise initiating means for moving said work holding unit off said conveyor to each of said machines and prepositioning it respective thereto, (b) means clamping or otherwise holding

it at said prepositioned position, (d) said work holding unit next commanding the movement of said tool respective to the work thereon, (d) commanding the stopping of said tool when said machining or operation is completed and (e) initiating the action returning the work holding unit to the conveyor.

(5) Systems whereby the actions described above are supplemented by automatic actions at the machines performed on the work which are initiated by movement of the work respective thereto but are easily adjustable at the machine to meet a variety of product requirements by the use of replaceable command recordings directing command systems inherent in the machines.

(6) Systems whereby some of the actions described above are supplemented by the provision of one or more limit switches actuated by the movement of the work motors directing motion of the work and/or said machines.

(7) ~~Systems for automatically storing and removing products from storage without man attention~~

It will be seen from the following descriptions and the accompanying drawings how I attain a high and most flexible degree of automation with a minimum number of positioning, clamping, work grabbing and work moving fixtures. This is accomplished by providing fixtures, and clamping devices which are flexible, capable of referring work clamped or held therein to base lines common to the machine tools and automatically adjustable to different work pieces or assemblies.

In order to simplify the discussion to follow, the following symbols will be utilized to abbreviate or define motions and components common to the devices and systems:

The letter "X" will refer to motions in the X direction, which is parallel to a line extending from machine station to station. As a subscript, X denotes a device such as a motor (M) associated with motion in the X direction.

The letter "Y" will refer to motions in a horizontal plane which are perpendicular to the direction of X or motions towards and away from (-Y) the machines at each station.

The letter "Z" will refer to motions vertically. Z and -Y used as subscripts denote devices or associated with vertical movements of the conveyor unit or machine.

The letter R refers to rotary motion of the tool, conveyor unit or work. U refers to motors driving said conveying units, work or tool or computer. W refers to work pieces or assemblies operated on. T refers to station machine, or machine tool. I refers to station machines which are an inspection devices. A refers to a station machine which is an assembly device.

In the conventional automatic production machine, commonly called the transfer machine, an article of manufacture such as an engine cylinder block is clamped in a chuck or holding fixture, prepositioned therein and placed on a conveyor which moves adjacent a series of machine tools. At each machine or station, said article of manufacture is operated upon by the tools of said machine. After it is handled by special devices associated with the particular machine which grasp it, pick it up off the conveyor, and move it to a position where it is operated upon by the specific machine tool. It can easily be seen how inflexible this set-up is. Any changes in the preset operations on the work or the sequence of said operations require expensive and time consuming changes in the kinematics of operation of each machine, if this is at all possible without completely altering the design of the transfer machine.

Whereas the aforescribed automatic production machine involves handling the work at each station by devices peculiar or adapted to that station, and the product, in my invention I attain a far greater degree of flexibility by rigidly fixing an array of machines, designed to perform particular operations (drill presses, borers, millers, grinding machines, lathers, honing machines, presses, welding machines, inspection devices, spraying machines, assembling machines, etc) on a variety of products, respective to a conveyor system which is so designed that all motion of said work respective to said machines is accomplished by a unit work carrier riding on said conveyor. I also provide automatic means for moving the tool respective to the work or the work to the tool, to enhance the flexibility and improve the precision of my system, but said actions are not necessarily peculiar to each station and may be quickly adjusted for any specific product. I have thus eliminated the necessity for having a work holding or moving device at many of the machines and utilize such apparatus or devices only where it is easier to so do or to improve the operation when necessary. When

this is done, I provide work holding means at the machine which is (a) automatic, (b) can be commanded by the work holding fixtures command system or is easily and rapidly adjusted or changed at the machine station.

One of <sup>the</sup> my conceived systems, the work is clamped in a conveying device and power means associated with said conveying device, is provided for automatically moving said work to any point in the vicinity thereof. This is accomplished by a command system which starts and stops electric motors in sequence to direct said conveying device to any position in the conveying area, such as to a predetermined machine. The action is followed by the further movement of the work automatically to said machine. Machining may be accomplished under command by (a) movement of the conveying unit and the work held therein respective to a machine cutting tool, (b) by prepositioning the work at the machine and directing or causing said tool to move respective thereto and (or) moving it further by the machine elements respective to the tool. The command system has a means peculiar to each product for predetermining the X, Y, and Z, coordinate motions of the work to preposition it respective to each machine and command any necessary motions of said unit during machining operations. The entire automatic operation on a product <sup>thus</sup> may encompass the complete production of said product from the raw material or, complete finishing operations on a partially completed product, which may include inspection operations and feedback commands for completion of the operation, and to correct the tool. What is essentially needed for products to be applicable to these systems is, means designed or inherent in each product for determining reference or base lines when it is clamped or held in a work holding fixture on the conveying unit, so that the command system may correctly direct proper motion of the various machine tools respective thereto.

The entire operation or sequence of operations on a variety of products may be predetermined as a function of the relative motion of the work holding devices. Servo motors driving the work conveying device may be controlled by pre-recording means and operated per se, or in conjunction with mechanical switches, electrical contact means or photoelectric cells actuated by movement of the work or work conveying units. Said pre-recorded command mechanism may employ any one of a number of mechanical, electrical or magnetic memory devices such as (a) a punched tape, (b) punched card, (c) magnetic tape, etc. which is coupled to a control unit which converts said recording to an electrical signal and mechanical motions. Machine tools per se have been run automatically by these and other preset or pre-recorded means which direct or command motion of servo motors or solenoids driving the tool.

at a predetermined rate in the ~~X, Y~~ and Z planes and in predetermined sequence thereto.

Fig. 1 is a plan view of part of a possible production line layout in the realm of this invention. The line may extend beyond the space limits shown. It comprises, in part, a track 21 or vehicle guideway, with a series of self propelled vehicles or work holding carriers 22 riding on said track. Said trackway preferably doubles back on itself or forms a closed circuit so that the individual work holding carriers 22 may arrive at the starting point of the cycle without backtracking. Adjacent to, or flanking said trackway are an array of machine tools T, inspection devices K, assembly machines A, finishing machines F, etc. In fact, any tool, mechanism or handling device capable of performing operations on work of a specified realm of manufacture may be provided along the line.

The basic component of this invention is a self propelled work carrying vehicle travelling on said trackway which is provided with mechanical and electrical mechanisms for moving the work respective to the tools. In my preferred embodiment I provide an overhead conveyor rail system on which said vehicle 22 rides. Extending downward from said vehicle is a vertical support or column 23 (shown in Fig. 2 and 3) which travels therewith along said track 21. The work may be held in a jig rigidly affixed to the column 23 and moved from station to station where the various machines operate on it. For a more flexible arrangement, I provide means whereby the work holding jig or platform 36 is movable respective to said column number 23, so that said work may be moved to and from each of said machines if necessary. Of the overhead conveying systems applicable to this invention, a monorail or bi-rail layout are conceived, each of which involves a modification of the vehicle column assembly and driving means.

#### Monorail System:

Figs. 2 and 3 show an overhead mono-railing or track 21 (illustrated as an I-beam though having any desired shape) which extends along and over a row or line of machine tools, inspection devices, automatic assembly mechanisms, finishing devices, etc.) as illustrated in Fig. 1. A carriage or vehicular dolly 22 is adapted to travel longitudinally thereon from station to station. Fig. 3 is a partially sectioned view of the track 21 and carriage 22 mount having wheels 24' engaging the I-beam web for lateral stability and a solenoid 65' mounted on 22 adapted to frictionally engage against 21 to lock the carriage 21 on the overhead track when so needed for machine operation. The suspended carriage 22,

24, mounting four or more wheels 21, which is adapted to run along said trackway with said wheels rolling on the flanges of the I-beams or trackway extending therefrom. Electric motor M<sub>1</sub> (not shown) is used to designate the motor speed control and braking mechanism associated therewith) is secured to said carriage 22 on a mount 26 and drives it by rotating wheels or an odd wheel 25 which frictionally engages the bottom of the I-beam or track flange. M<sub>1</sub> is supplied with electrical energy from two conducting wires or rails 28 which are mounted to extend parallel to each other and to the trackway 21. Contact therewith with brushes 27 extending from the carriage 22 which either sweep or roll on said wires 28 provided electrical connection between a power supply and the servo motors associated with the conveyor assembly.

The vertical column 23 extends from the carriage 22 and may be rigidly affixed thereto, rotationally mounted as in Fig. 2 or arranged to telescope on itself to provide vertical motion or rotational motion of the work clamping or holding assembly mounted below. By rotating the column 23, greater flexibility is added to the device as the work held below may be rotated respective to the station machines. This may also be of advantage in automatic loading and removal of the work from the conveyor unit. Rotation is accomplished by the use of motor M<sub>2</sub> which is mounted on the side of carriage 22 to rotate the column 23 thru gears 33 and 34. The latter gear 34, is shown extending peripherally about the upper end of said column and is rigidly to the top thereof at the flange 30. A vertically extending bearing pin or axle 31 having flanged ends 32 rotationally supports the column assembly below carriage 22. Tapered roller or ball bearings 49 are mounted therebetween and reduce rotational friction. The work W is secured in a work holder which comprises a platform 35 extending laterally from column member 23 and mounted to be movable in and out thereon or providing movement of the work-clamps or jig 36 laterally respective to 23. The numeral 36' refers to a solenoid or servo motor coupled to move the vise or clamps 36. The platform 35 is movable laterally on a cylindrical column 35' and may be locked in any position thereon. The column 35' is also movably mounted respective to 23 by being slidably mounted in a bearing member 38' extending from collar 38 which in turn is slidably mounted on column 23. Motor M<sub>2</sub> mounted off 38 drives 35' thru spur gear 39 and spur 39', the latter being mounted rigid respective to 35' on bearing lugs 40. which are mounted off the column 38 to clear collar sections 37 and 38'. Various other means of driving the platform 35 are feasible. An arrangement permitting access of W to both sides of 23 would eliminate the need for rotating the column 23. Also, if the tools of the machines M<sub>1</sub>, A, I, F, S, H, G, H<sub>2</sub>

which are employed are ~~provided~~ with automatic means for moving respectively to the station. It may be commanded to describe the necessary motions respective to the work, it would not be necessary to move the work held by the column and it (the work) could be rigidly mounted thereon. In such an arrangement, the system would comprise an array of ~~self~~ <sup>covered</sup> carrier-column assemblies moving one behind the other on the conveyor line and stopping in front of selected machines.

It has been shown how the device of Figs. 2 and 3 moves the work laterally to the conveyor track. Movement up and down on the column is obtained by provision of servo motor  $M_2$  the shaft of which is coupled to a screw or worm 42 fitted with a threaded collar 43 which is secured to a cross-bar 44 affixed at its ends to the collar 38. The bar 44 is guided in vertical travel in the slots 45 in the column 23 and moves up and down with the turning of screw 42 by motor  $M_2$ . 41 refers to a base or cap of column 23 on which  $M_2$  is mounted. The numeral 41' refers to a bracket secured to the wall of column 23 which supports the end of screw 42 in bearing. It is noted that various other mechanical or hydraulic arrangements may be utilized to move the collar 37 up and down on column 23 such as worm and spur gear drives, chain drives, etc.

The motors  $M_1$ ,  $M_2$ ,  $M_3$  and  $M_4$  are powered by electrical energy supplied thru brushes 27 riding over the electrical conducting rails 26. While  $M_1$  and  $M_2$  are directly accessible to the brushes 27,  $M_3$  moves up and down on base or collar 37 and  $M_4$  is situated within the column 23. If  $M_4$  is utilized in the design, making the column turnable respective to the carriage 22, the conducting elements or wires from the brushes 27 are most conveniently connected to the motors below by passing thru the center of rotation. They are shown passing thru the center of pin 31 and extending to the motors  $M_3$  and  $M_4$ . The numeral 47 refers to a computer used to direct automatic rotation of the motors  $M_3$  and  $M_4$  described and will be discussed later. In order to allow for the vertical travel of the assembly of 30 and the components mounted thereon, motor  $M_3$  is electrically connected to the electrical system of the column 23 via wire 46 which has sufficient free play to account for travel.

- 14 -

Load wire 46 is flexible and long enough to permit 38 to ride up and down on 23 from its highest position to its lowest. By operating the motor controls Mx, My, Mz, etc., in the proper sequence the work W may be driven to any particular station along the conveyor line or trackway, moved towards the machine, propositioned in the Z direction, moved respectively to the tool during its operation thereon, removed and returned to its aisle position and moved on to the next stations. The entire action may be predetermined by a presetting or recording command device 47 or may comprise a combinations of commanded actions, supplemented by automatic actions initiated or controlled by limit switches or photoelectric devices common to the system and actuated by movement of the carriage column assembly or work holding platform 35.

Fig. 4 is an end view of a work conveyor unit utilizing a biraill trackway running overhead and past an array of production machines. This arrangement may utilize the column 23 and carriage 22 of Figs. 2 and 3 which rides laterally (to and from each machine) on the crane crossbridge 52 which may also be an I-beam. Wheels 24 supported at the ends of 52 ride on a track 54 mounted on the upper surface of the trackway I-beams 53. Motor Mx drives the bridge along the track 54 thru gears G and G'. The verticle columnar member 23 of Figs. 2 and 3 is shown modified in Fig. 4 to illustrate another possible design. In Fig. 4 the column consists of two sections, an upper tubular section 23' secured to the bottom of carriage 22' and a lower columnar section, circular in cross-section and slidably mounted to telescope into the bottom of 23'. Secured to this lower section 23' near its lower end is a laterally extending shelf or platform 35 on which a work holding bed or mount 38 is mounted. The motor Mx mounted on 35 is coupled to drive 23' up and down therein via spur gear 39 and spur 39' which is secured thereto to the upper end of 23'. Rotation of the column assembly may be accomplished as in Figs. 2 and 3 but is not shown in detail in Fig. 4 which is used only to illustrate the cross-bridge doll-column arrangement. The notations Mx, My, Mz, etc. refer not only to these servo motors but also to their controls including braking mechanisms for stopping them on command in a specified time duration after receipt of the signal to stop.

A preferable system for determining the type, degree and sequence of motion required to perform specified operations on a product moving in the system is one wherein the various work stations or machines are identifiable by a device at the work carrier which initiates or commands actions upon identification.

Fig. 3' is a cross-sectional view of the upper section of Fig. 2 showing means further holding the column-carrier assembly at the station by use of a solenoid 65' mounted on 22 the ram 66' of which automatically engages the flange of 21.

mechanical means, Fig. 6 and 8 show mechanical means whereby the travelling column and dolly assembly may identify the work stations in the X or conveyor travelling direction. Once said station is so identified the dolly may be made to automatically stop permitting the machine at the station to perform its operation automatically thereon at its stopped position or do so following movement of the work to the machine to attain predetermined position at the machine.

Identification of the station may be accomplished in one of several manners. Fig. 5 is a partially cross-sectional view of the conveyor and dolly and Fig. 6 is a partial side view thereof. Identification is made by the use of a limit

switch or switches 69 mounted on the dolly base 22, the arm 60 of which is depressed or thrown as the dolly passes pins or projecting elements 61 extending from the flange of rail 21. Said switch 69 is in series with the motor MX

driving the dolly or may be coupled to sequence command computer 47 in a circuit which will initiate a series of actions stopping the dolly, positioning the work and starting and stopping other motors operating the conveyor or station machine

mechanism. The arrangement of Figs. 5 and 6 shows two pins 63 and 62 spaced laterally apart and a distance apart from each other in the X direction on the rail flange 21'. The throwing of the first switch by 62 will turn off or slow down the motor MX. The throwing of switch 60 by 63 may be coupled to a brake

stopping MX and the dolly at a precise X position. One switch would suffice if it, in addition to shutting down motor MX it were coupled to a solenoid 65 actuating a pin or projection 66 to extend against the conveyor railing and become

engaged in hole 67 therein, thereby stopping and (or) locking the dolly respectively to the conveyor at the desired station. Here again the solenoid and switch preferably are coupled together thru the station selecting component of the command

computer making it possible for the dolly assembly to select certain stations while bypassing others if necessary.

Another means of work station identification and selection is shown in Figs. 25 and 8 which illustrate photoelectric cell 68 and light source 69 combined and mounted on the side of 22 to scan, for example, the upper flange of base 21.

Slow  
Down  
&  
Stop

25  
30

*on the*  
A small reflector 70 placed on flange 21' of the I-beam will reflect the beam from the light source back into the phototube and may thus be used to identify the machine station. Said photocell is in a circuit with a photoelectric control which causes a relay to close a switch when light is reflected from 70. The closing of said relay actuated switch may be used to initiate an action braking the assembly and signal the device commanding motion of the work holding platform 36 to move it towards the work. If the command computer 47 is utilized, the closing of said solenoid actuated switch may be utilized to signal the computer which by use of a mechanism such as a multiple circuit predetermined counter may be used to determine whether or not the machine at the station is to operate on the work.

Fig. 8 is merely a variation of Fig. 7 whereby the photocell 66 is secured to the column 23 and is energized by light reflecting off reflector 70' positioned near the base of the machine tool MT.

Fig. 9 is an end view of a production line arrangement in the realm of this invention wherein the bi-rail work conveyor assembly of Fig. 4 is utilized. Station machines 71 and 72 situated on either side of the conveyor line are utilized to support dual I-beams 53' and 54' and thereby eliminate the necessity of providing mounts or ceiling brackets for said trackway. If modified standard-power tools are utilized, the machine frames, which are designed to resist machining forces, may be sufficiently strong enough to support the overhead rails and the forces of machining. If not, re-enforcement of their vertical members may be necessary. The I-beams or tracks 53' and 54' are shown modified with a V or wedge shaped indentation 74 extending from the upper surface downward there-in. This is used to center and provide lateral support to the wheels 24' riding thereover and is accomplished by providing a wedge shaped circumferal projection 24" at the center of the outer circumference of each wheel. Said construction reduces the amount of side play in the assembly during machining and serves as a guide for the wheels as they travel along the trucks. The numeral 71 refers to the bed of either machine on which the platform rests prior to machining. Also shown in Fig. 9 is another means for holding and supporting the work at the machine while being worked on. This is accomplished by use of an electro-magnet 73 in the machine bed 71' which is energized by a switch SW actuated by 47 under command or by movement of the conveyor platform 36, working 36 or workW and engages 36, 36 or W depending on how the work is held and conveyed about the system. Also

103  
shown in Fig. 9 are the electrically conducting rails or wires 28, which are held by brackets 79 insulatedly mounted off the frames of the machine tools 71 and 72, or mounted off the I-beams.

Fig. 10 shows a mono-rail trackway 21' supporting and guiding a modified conveyor assembly from machine to machine. Said track 21' is supported by the frame of the machine and is mounted thereon at the upper front section thereof as shown. The numeral 21" refers to a support extending from the top of the machine frame to the track 21'. The modified conveyor carriage comprises an open channel shaped dolly rotationally mounting wheels 24' and 24" which are vertically supported in bearing by the walls of said carriage and which ride against the inside and outer face of the outer flange of the I-beam 21'. The motor M is coupled to the shaft of 24" which rides on the outer face of the I-beam flange and drives said wheel to move the assembly along the trackway. While the end view of Fig. 10 only shows two wheels, four or more are preferably utilized to stabilize the mounting. Said wheels are mounted behind 24' and 24". Wheel 24" is shown wedge shaped at its rim in cross section and said rim rides in a wedge shaped groove in the flange of the trackway 21'. This construction is utilized for purposes of alignment of the assembly of 22' and 23 respective to the track 21' and hence the machine or machine tools. It is noted that the overhead track 21' of Fig. 10 need not be supported by the machine frames as illustrated but may be mounted hanging from the ceiling or from poles or supports extending from the floor.

The work holding jig 36 shown in Fig. 10 is modified to hold several smaller work pieces, each of which is to be operated on by the machine tool at the station. It is illustrated merely to show that system is so versatile that it is adaptable to take not only heavy work such as automobile engine cylinder blocks which are run thru the conventional transfer machine but also a variety of smaller item one at a time or in groups mounted on a single work conveyor unit. The basic requirement for the particular product handling and operational problems is the provision of the proper work holding jig or clamps 36, means referencing work held therein to the conveyor assembly and (or) the machine tool base. The letter S refers to an adjustable stop (adjustable in and out) the back face of the machine bed MB (referred hereafter as 71') against which the platform 35 or work jig 36. The letters SW refer to a limit switch(s) mounted on S and (or) 36 which may be utilized to stop the work at the machine and start the machine in operation when 36 is positioned. SW<sub>a</sub> is a limit switch on 71' which may be used to stop the longitudinal travel of 36.

various means of securing the work conveyor lateral  
platform 36 or column 23 at the machine and electrical coupling means and  
control switching devices between the machine and conveyor. It is not necessarily  
intended in the drawings to present a particular system of automatic man-  
ufacture or, in this application to discuss at length the elements of servo-  
mechanism systems necessary to perform precision machining operations using the  
mechanical handling components heretofore described or, to discuss in detail  
electromechanical and electronic computing devices for commanding precision  
operations by precisely controlling the movements of  $M_x$ ,  $M_y$ ,  $M_z$ , etc. Suffice it  
to say that the letters  $M_x$ ,  $M_y$ ,  $M_z$ , etc. refer not only to electric motors  
generating a particular motion but also to precision controls of the motors  
guaranteeing a constant speed, predetermined rate of change of speed, predetermined  
type of reversing and braking. Where a machine tool MT is shown, for the  
particular embodiments or combinations of Figs. 11 to 15, it is assumed that  
the tool MT is preadjusted or commanded to perform in a given manner respective  
to the work and that said action is initiated by motion of the work or work con-  
veyor relative to the machine, or is initiated and controlled by the command  
computer 47 which may be a simple electro-mechanical device opening and clos-  
ing switches starting and stopping said motors after predetermined time inter-  
vals or may be more complex analog or digital computing devices commanding said  
actions and working off magnetic, electrical or mechanical memory systems.  
Switch means has been shown in Fig. 5 for stopping the vertical column 23  
opposite the desired station. The action opening switch 50 which stops the  $M_x$   
motor and brakes the conveyor motion may at the same time be utilized to close  
a circuit starting up  $M_y$  to drive platform 36 to the machine bed 71. This may be  
accomplished by providing switch 59 as a double acting switch which closes a  
circuit with  $M_y$  when it is depressed and  $M_x$  circuit is open or by providing a  
second switch adjacent to 59 which is compression closable and closed by project-  
ion 61 at the same time 59 is opened thereby closing switch 69, situated on the  
end of platform 36 and actuated when the platform makes contact with the machine  
bed stop 8 or base upper surface 71. It may be used to stop motion of 36 by opening  
a circuit with  $M_y$ , and also may be utilized to initiate other actions such as  
further securing of the platform 36 at the machine, clamping or unclamping of  
the work held thereon, release of the work, initiation of actions picking up  
the work, etc. Another switch or switches situated at the machine may be used

to initiate still other desired actions such as ; further means securing the platform 35, the work, or the work holding jig 38 or section thereof at the machine by holding devices associated with the machine; means moving the work off the platform 35 to the machine bed 71; movement of the machine bed MTB or the machine tool MT' respective to and on the work after a delay permitting required operations such as clamping or holding the work, zeroing or prepositioning the work, etc.; Still another switch associated with the machine may be actuated upon completion of machine operations on the work at the station by, for example, withdrawal of the machine tool (as in Fig. 15, switch 60' contacted by projection 60" extending from the tool head MT' ) may be utilized to signal the conveyor to withdraw the platform 35 from the machine by actuating a solenoid ram 93' to close a switch 88 on the platform 35 which in turn closes a circuit with a solenoid switch in the My control which remains closed, reversing My to drive 35 away from the machine MT until stopped when the platform has been fully withdrawn. If the bimail system is utilized, the mechanism stopping My may be similar to the mechanism of Figs. 5 and 6 stopping Mx. A projection 63 as in Fig. 9 closes a switch similar to 59 mounted projecting from 22' opening a circuit with hydromechanisms stopping or braking My. The projection 63 may also be utilized to depress a switch mounted on 22' closing a circuit with Mx and a power supply and starting the motion of the assembly to the next station or machine.

Thus it is seen that a command system (based entirely on limit switches and stops along the trackway, on the column 23 or work platform 35, at the machine tool MT bed 71' or at other points on the machine coupled with solenoid or other actuated means signalling the completion of ending of operations by the machine to the conveyor) may be utilized in one system of automation. In such a system it is required that the machines be adjusted or commanded to perform in a predetermined manner on the work. While this arrangement is not applicable to more than one product at a time on the line, nevertheless the system could be made very flexible by the provision of a quickly changeable and easily alterable command system such as that of Figs. 20 and 21. The system also requires the use of circuits involving the use of hold down switches which may be closed or opened by a pulse of current initiated by the actuation of one of the limit switches aforescribed and to be described which are used to indicate motions and positions of the various movable parts of the system.

Fig. 11 is a partial view of a production line work station showing an overhead conveyor driven verticle support column 23 of the invention with means provided to support said column at the station against bending moments thereon and hence against deflections thereof when for example lateral loads are imposed by a horizontal cutting tool such as the drill 75. Means for steadyng and positioning the column 23 and hence the work W against axial loading comprises a verticle support or frame 76 positioned on a base 77 and mounted on the floor at the station to resist the forces of the cutting tool thereagainst. When the column 23 is opposite the machine tool 75, it stops and is automatically backed or supported by 76. The tool then performs on the work and loads are transmitted thru W, 35 and 23 to verticle 76, thereby improving operations while the work is held by the conveyor unit.

Several means of automatically engaging the verticle column 23 during the machining operation at the work station are shown in fig. 11. One method comprises utilizing a shaped bucking bar 78 secured to 76 and positioned to engage a mated bar 79 mounted on the column 23. Fig. 12 shows an end view and a partial isometric view of the bucking bar 78 having a wedged shaped longitudinal indentation 78' therein adapted to engage and mate with a longitudinal wedge shaped projection 79' extending from 79. Either or both 79' and 78 are tapered to permit ease of engagement between the two as the column 23 approaches 78. The numeral 80 refers to an electro-magnet positioned on 76 to draw 79 against 78, and thereby add additional support to 23 during machining operations. The numeral 80' refers to a second electro-magnet facing and adapted to engage 23 which may be used per se or in conjunction with 79 and 80. A switch SW projecting from 76 to engage 23 with its motion to the station may be utilized to energize 80 and (or) 80'. Disengagement of the electro-magnets and 23 may be attained by a solenoid energized by the afore described command computer 47 or motion of the tool 75 as it finishes its operation on the work and withdraws therefrom thereby actuating a limit switch (see Fig 15). The numeral 75' refers to the base of the machine or machine tool 75. SW refers to a limit switch projecting from 75' which is utilized to initiate action of 75' on the work W.

Fig. 13 is a partial end view of a work conveyor unit at a station machine MT showing another means for engaging the verticle column and supporting it during machining operations. Although not shown, all actions are initiated by either limit switches projecting to be closed by motion of the column 23 or by

103. or by the use of electric devices or by the use of photo electric devices at the station. In Fig. 13 I show 2 means of physically engaging the column 23 which may also be used to engage the lateral platform 35. One means comprises the utilization of a solenoid actuated ram or pin 81' adapted to be moved by said aforescribed station mounted limit switch or photo cell actuated switch against said column 23 or engaging a hole 87 therein. This serves the dual function of both positioning the column at the station in supporting it against lateral machining loads. The numeral 81' refers to the solenoid actuating pin 81' which is shown mounted on a projection from the base 71 of MT, and projecting upward therefrom to engage the bottom of 23. I also show in Fig. 13 a solenoid 81" projecting laterally from 71 which may be used in conjunction with the aforescribed solenoid or by itself. Two of said laterally projecting solenoids may be used to wedge the column 23 therebetween and thereby position and steady it. Still another means of engaging 23 at the station is to use electrically actuated clamps which are not shown and which altho more costly than the solenoids per se may be necessary for certain types of machining operations.

Also illustrated in Fig. 13 is a more versatile machine which may be used to add flexibility to the operation in the event that x, y, z, and rotational motions of the tool respective to the work are necessitated. While it is not intended to go into the finer details of the mechanism of the machine of Fig. 13, the major components of said machine are described in order to understand their function and their relation to the automatic production systems of this invention. The machine tool frame MT and upper section MT' which is rotatable thereon by motor MT<sub>R</sub>. The machine tool head 82 is mounted on a column or trunk 82' and is drivable thereon towards 23 by the motor MT<sub>Y</sub> mounted on MT'. The motor MT<sub>Y</sub> drives the cutting tool of 82 up and down and a motor mounted in 82 may be utilized to rotate said cutting tool. The motor MT<sub>X</sub> mounted on MT' may be used to drive the assembly of MT', 82' and 82 parallel to the conveyor trackway. The machine of Fig. 13 may be utilized in automatic production systems having features aforescribed and particularly to be described in Figs. 14 to 17. Fig. 14 is a partially cross-sectional partial side view of the end of a rail holding frame 35 and part of the work table 71 under the tool head MT. The platform 71 is driven towards the tool bed 71' until it comes to rest against the wall or backing 8. The numeral 63 refers to wires mounted within bed 35 and extending from a sequencing command device to be described. Said device to be mounted

may be mounted within the platform 35 or column 23 and, as heretofore described, may be utilized to command selection of station machines and (or) their particular performance on the work W. (See Figs. 20 and 21). The device, previously designated by the numeral 47, may command, in addition to station selection, such actions as engagement and disengagement of the work conveyor column 23, at the station, the platform 35 at the machine bed 71's, prepositioning of the work W respective to the machine, removal of the work W from its conveyor holding jig 36 and its prepositioning and clamping at the machine toolbed, motions of the machine tool respective to the work and, unclamping and removal of the work from the machine. To accomplish these functions the computer 47 may, as stated, be mounted on or in the work carrying conveyor, and array may be mounted one at each machine to be started by the approach of the work holding conveyor, or the actions of the machine may be commanded from the conveyor mounted computer 47. In order to convey electrical signals from the work holding conveyor such as those originated at the computer 47, to the various station machines and visa versa, I provide simple electrical coupling means between the conveyor lateral platform 35 and the machine tool bed 71'. Wires 83 extending, for example, from the computer 47 are connected to surface mounted contacts 85 and 86 which are mounted on the end of 35 and are positioned to make contact with similar contacts 86 and 87 mounted on the machine tool base 71' or the end of the base 8 and electrically connected via wires 87' to electrical devices associated with said machine. <sup>In Fig. 14</sup> <sup>two types of</sup> contacts are shown, both permitting flush mating of 35 with 71'. All contacting elements are insulatedly mounted on their respective bases in a housing 84' which is made of a nonconducting material. The upper contact 86 is a female conducting receptacle adapted to mate with the male fitting 87 thereto opposite mounted on 71'. The lower contact 85 is mounted on a spring 85' and normally projects beyond the surface of 35. It makes electrical contact with jack 86 projecting from 71' which pushes 85 into the housing 84' permitting flush coupling of 35 with 71'. The command signal from 47 may comprise one of several electrical variables which direct a mechanical or electrical device or which commands a computer directing the tool to ascribe a predetermined action. Conceived signal variables are (a) a constant voltage signal to a servo motor, the time duration of which determines the amount of rotation of said motor which determines a particular motion of the machine tool or devices associated therewith. (b) a variable voltage, the variations of which move a potentiometer to control directly or indirectly a mechanical action thru an electrical servo, (c) pulses of current, each or a group of which command

actions of a motor, solenoid, computers, and other electrical devices. For example, pulses from computer 47 may be used to set a computer at the machine for the purpose of commanding inspection devices which function with feedback information being recycled to said computer to maintain quality control and keep the product within quality limits regardless of the wear of the tool. Or, the computer 47 may be electrically connected with inspection devices mounted on the work carrier such as x, y, z, electrical probes contacting the work to determine whether or not tolerances have been met by the machine. Two sets of mated contacts are shown in Fig. 14. In actual practice, where there are a number of circuits involved, an array of said mated contacts would be provided to account for a variety of circuit connections between the conveyor unit and the machine. Fig.

Fig. 15 is a partially cross-sectional view of the end of the platform 35 and the station machine bed 71 showing the aforementioned limit switch SW, designated as 89, and a switch 88 projecting from the bottom of 35. The switch 89 projects from the end of 35 and is utilized to signal the arrival of 35 at the end of 71, for example, turning off motor M<sub>2</sub>. Shutting down M<sub>2</sub> may signal the lowering of platform 35 until it is flush with the top 71' of bed 71. This is accomplished by providing the switch 89 as a two way limit switch, the projecting position illustrated permitting the closing of the circuit of M<sub>2</sub> and a power supply and the inner position attained by the end of 35 butting against 89 opening said M<sub>2</sub>-power circuit and closing a circuit with the control of M<sub>2</sub> driving it downward. The switch 88, also a two way switch, when in the position illustrated (projecting outward) permits an closed circuit with M<sub>2</sub> and a power supply. When it, 88 buts against the top 71' of base 71, it opens said M<sub>2</sub>-power circuit stopping M<sub>2</sub> thereby bringing 35 to rest. The motion of the machine tool may be initiated by a limit switch SW mounted thereon to be closed by motion of 35 butting thereagainst or by signals from 47 thru the coupling of Fig. 14. When the operations at the station have been completed, 47 may signal the removal of 35 from the machine bed 71 or said action may be signalled as follows: I provide one or more solenoids 93 mounted in 71 in a manner permitting its ram 93' to be projectable above the surface thereof when said solenoid is actuated. When the machining operations have been completed and the tool head is being withdrawn a limit switch 80' mounted near said head may be actuated by the movement of said head M<sub>1</sub>'s. Closing of 80' may be utilized to cause the solenoid ram 93' to project above the surface of 71'. If 93 is positioned opposite 88, it may be

it may be used to further move 88 to a third position which again closes the circuit with  $M_2$  and a power supply. This will cause  $M_2$  to lift the platform 35 and although the switch 93 goes thru a neutral or open circuit position, the switch SW may be adjusted to open again retracting 93' and permitting 88 to quickly assume its first position which again closes the circuit with  $M_2$  and the power supply. The utilization of the combination of the command computer 47 directing actions which are initiated, stopped, altered or supplemented by a system of limit switches permits the attainment of a very flexible degree of manufacture in that each work conveying unit may carry command instructions peculiar to the particular product it is conveying. Two different products, for example may follow one another on a singel production line, the command system of each selecting the proper machines and commanding them to perform accordingly on the work held thereby.

The initial cost of an automatic production system having individual work conveying units each with its own command computer is high and is economically desirable only where large runs of a variety of products are made. In Fig. 16 I show components of a system of automatic production which, although not as flexible as some of the aforescribed arrangements, would suffice for certain types of production such as large runs by a concern manufacturing but a few products. The system is flexible in that each production machine flanking the conveyor trackway 21 is capable of being command operated by its own computer 47' which is easily changed or altered. The machine tools of each of said machines  $M_1$  are capable of being moved in a desired volume by servo motors  $M_{1x}, M_{1y}, M_{1z}, M_{1r}$ , etc. The work  $W$  is held in a clamping jig 36' which is mounted on a platform 35' which is rigidly secured to column 23. The letter  $M_{1b}$  refers to a clamping or holding servo or work conveyor situated at the base 71 of the machine  $M_1$  which is actuated to clamp or hold the work  $W$  or the platform 35' by the motion of 35' or  $W$  past a limit switch associated with  $M_1$ . When the work  $W$  and (or) platform are held at the machine, the tool under command of its computer 47' is driven by its motors in sequential  $x, y, z$ , and rotational motions to operate on the work  $W$ . The numeral 73 refers to electromagnetic means for holding the platform 35' at the machine bed 71 and 73' to electromagnetic means for holding the work  $W$  against 35' if so needed. The means stepping and starting the work conveyor opposed the machine  $M_1$  is similar to that of the device of Fig. 15 whereby a solenoid mounted projecting from the base 71 opens a limit switch 95 projecting from 23 stopping  $M_1$  and when the machining is completed, 93 is actuated by 47' to again close 95 starting up  $M_1$  again to drive the conveyor 23 to the next machine.

- 27 -

Fig. 17 is a partially crosssectioned partial side view of the aforescribed conveyor platform 35 at the machine tool bed 71, showing a design permitting the circulation of cutting coolant and lubricants originating at the machine tool to flow over the work and back to the machine for recirculation. Another function in successful automatic machine tool operation is the removal of chips, grindings or other product wastes and I provide for this required function by removing said wastes from the machine with the removal of the work holding conveyor unit. At some convenient point along the conveyor line said wastes may be blown, washed, dumped or otherwise removed from the unit. Housekeeping at each machine is thus minimized and requires but a minimum amount of human attendance. It is conceived that machining wastes could be removed without difficulty by a separated belt or tubular type of conveyor but this would add considerably to the cost of installation.

In Fig. 17 I provide ducting in the form of thru and thru drilled holes 97 thru 35 and 35' which will align with directing 98 in the machine tool bed 71' during the machining operation. The base of 35 is sloped towards these holes so that oil flowing over the work there in will not collect but will flow therethrough. The numeral 97' and 98 refer to the countersunk upper section of each hole to improve the collection of the oil, prevent overflow and account for variations in the alignment of the holes 97 and 98. The numeral 99 refers to a ducting in the base of 71', 99' to a ducting therein leading to an oil pump for returning the oil to the system. A tray or fence 96 is provided surrounding work holding jig 35 to catch chips or waste falling off or flowing from the work. Said tray may be automatically pivoted or removed, turned or dumped to clean out the waste therein. Another alternative may be to run the assembly at 35' thru a bath of solvent to remove all waste, oil, etc. The letter Y refers to filters in lines 97 and 98 to filter the coolant or oil flowing therethrough.

Fig. 18 and 19 show a work holding conveyor which, unlike the aforescribed automatic conveyor units does not ride on a trackway, but travels along a continually moving conveyor belt 107. FIG. 18 is an end view of said unit on the conveyor 106 and FIG. 19 an isometric view thereof. The conveyor work-holding unit may be designed with any desired degree of complexity depending on the desired degree of automatic manufacture, which in turn would depend upon the particular production requirements and the number and type of machine tools flanking the production line. The unique feature of this arrangement is that characteristics of the conveyor unit 100 such as its shape, may be used to (a) detect the unit and automatically move it off the conveyor to the machine, (b) preposition the unit and work held therein respective to the machine and (c) act as a holding member or intermediary holding member at the machine thereby prepositioning the work and (d) as a means of referencing the work at the machine.

The work-holding unit is shown as a cubicle 100 open at the top with a flat bottom 101 which rides on the conveyor 107. The cubicle 100 may be designed per se with a rectangular opening therein and having clamps, C1, C2 and C3; or may have any shape convenient to move along on the conveyor and to hold a product or products.

In the device of FIG. 18 and 19, I show a work holding and conveying unit 100 having automatic and adjustable clamps C1, C2 and C3 driven by servo motors, or solenoids MC1, MC2 and MC3 (not shown). The clamps may be shaped to the contour of the face of the product. They are shown as flat plates. They may also be made of a flexible material such as rubber if the work in process does not require heavy machining operations and can be referenced respective to the jig 100 by being forced against the jig inner walls by the clamps. The faces of the clamps are also preferably removable to account for differently shaped work to be held.

Two types of production line set-ups are possible using this work-holding conveyor arrangement. They are (a) a production line having an array of machines and machine tools adjacent to the conveyor 107 and an array of individual jigs carrying work in process which is held in each jig 100, and transported thereby from one machine to the next automatically conveyed to each where an operation or sequence of operations are performed thereon. Said set-up is inflexible in that each machine must be adjusted to perform a specific operation on the jig.

hold work. However, it is low ~~initial~~ <sup>in initial</sup> cost. More important is that each station machine ~~can~~ be designed to accommodate the outside dimensions or shape of the jig 100 and as such may be easily adjusted to alter its operation on the work. In other words, the feed, speed and degree of travel of the cutting tool are the only variables which need be changed for operations on different work in process, not the means of handling or clamping the work at the machine, whereas the conventional transfer machine is designed only for a specific product; (b) a production line having an array of machines flanking a conveyor and a series of work holding jigs 100 riding on said conveyor which contain means for (a) selecting predetermined stations and (b) commanding action of the tool at each of said selected station on the work held thereby.

Fig. 18 shows the more elaborate design (b) for automatic production whereas Fig. 19, the isometric view, shows design variations which could be applicable to either (a) or (b). Both Fig. 18 and 19 show photoelectric cell means of station or conveyor jig 100 identification. Needless to say, mechanical identification means involving the closing of switches at the station by the work carrier may also be utilized to advantage for this function. The simplest mechanical means involves the tripping or closing of a limit switch projecting outward from the conveyor wall which is thus actuated by the passing of the unit 100. The action would cause the ram to push the conveyor unit off the main conveyor 107 onto the station platform with sufficient velocity to butt against the stop or wall S. Once at the station a second limit switch 115 is actuated by the movement of 100. Switch 115 is in circuit with positioning and or clamping or holding means at the machine adapted to operate on the unit 100 prior to machining operations on work therein. As all work held in 100 may be easily referenced respective to the bottom and side walls thereof, said work will be referenced or positioned responsive to the machine tool when the work-holding unit 100 is rigidly held at the machine in a prepositioned attitude or position at the machine. The clamping or holding means at each machine may be standardized and (or) similar if all the holding jigs are standardized and (or) similarly shaped. The problem thus becomes one of designing or adjusting the jig clamps C1, C2 and C3 to hold a particular piece of work at the correct attitude and position it so that it will be referenced respective to the walls or characteristics of the shape of the outer surface of 100. The station machine MT, etc may then be pre-adjusted or command operated to perform a particular operation or sequence of operations on the jig held work.

- 43 -

In the warehousing or storage of manufactured goods a prime factor of cost is incurred in materials handling. The direct labor of transporting and item to be stored into the storage area, stacking or otherwise positioning it on its particular storage shelf, rack or palletized arrangement and picking it up and removing it when needed for processing or shipping has been greatly reduced by the use of mechanical materials handling equipment such as lift trucks, conveyors, cranes, etc. However, said materials handling equipment requires direct labor for its operation and at least one man must accompany the equipment to and from the storage area, position it in front of the stored item, lift and remove it. This not only requires time for human reactions to start such required functions as seeking, finding, repositioning the materials handling device, judging and moving the equipment, etc, but also requires the close and full time attention of an operator.

I hereinafter present a new and improved materials handling system whereby materials are handled to and from the storage area in an efficient orderly manner with a minimum use of human effort. Movement of materials to and from a storage area may also be rapidly expedited to and from a storage area at a rate which is faster than any accomplished by human attended equipment.

J.H.L.

41  
41

Modifications of the aforescribed machine and control components may be utilized to advantage in storage operations whereby products or raw materials are palletized, boxed or can be made into a shape which is easily stacked or arranged on shelves and is capable of being picked up by a grabbing device or forks. The system to be described is particularly useful in completely eliminating the necessity of the man traveling to and from a storage area to either handle or direct handling of a product for its storage or removal. The entire system is automatic and may be directed from a remote location. The system is of particular value where a rack shelving system is provided on which to store and stack packaged items or pallets, said storage system extending not only laterally in the X, Y plane but also a number of tiers in height. Fig 24 shows such a system whereby said racks or shelving are divided into a number of unitized storage volumes. Each volume may be identified by an X, Y and Z coordinate. The X coordinate will determine the aisle in which the unit volume is located, the Y coordinate the floor location in that aisle and the Z coordinate, the number of unit volumes high the particular volume is located. By utilizing some of the aforescribed components and an adjustable quickly settable command device for locating any particular unit volume, the monorail or bi-rail overhead conveyor systems combined with the vertical column 23 may be utilized to automatically store and remove palletized or boxed utilizing forks, rams, grabs, etc. This may be accomplished automatically in a manner involving a minimum amount of labor, handling, or attention. For accessibility, the unit storage volumes are arranged in rows of  $Rx_1, Rx_2, \dots$  on aisle between each two and accessible from an end row of aisles  $Ry_1, Ry_2, \dots$ . Assuming that the storage area is designed as in Fig. 24 with rows of multi-tier racking volumes 150 each accessible to an aisle  $Rx_1$  from an end aisle  $Ry_2$  by the overhead crane column and lift of Fig. 24, let the following letter and symbols designate travel of said materials handling device to and from a storage volume.  $Y$  is assumed to be the distance traveled along the outer aisle by the dolly and column and  $Y_1, Y_2, Y_3, \dots$  will therefore designate the aisles 152 between the racks numbered for identification from one end;  $X$  is assumed to be the

- 45 -

*3. aisle*  
*4. volume*  
*5. section of shelf*  
*6. height travelled by the lifting platform or forks*  
*7. height location in number of bays above the floor of any particular volume*  
*8. letters R' and L' refer to right and left hand sides of the aisles Rx of Fig. 23*  
*9. letter Y' refers to the distance travelled by the forks 153 from the aisle*  
*10. stopped position of the conveyor in towards the bay to under the pallet 154 or tote box therein. If other means grabbing or holding the work are used, Y' will refer to that action of said conveyor mechanism from the aisle stopped position of the column 23 to the storage bay to effect engagement or lifting of the load from the bay. The letter Z' refers to the lifting or vertical motion of the pallet or box 154 necessary to effect its removal from the racking by the forks 153. The letter -Y' refers to the motion of the forks 153 in withdrawing from the storage rack a degree into the aisle sufficient to permit further movement of the conveyor down the aisle. The letters -Y, -Z and -X refer to travels of the load on the forks or the forks empty from the aforementioned aisle position down the aisle Rx and along Ry, if necessary to a position where it comes to rest pending further commands or prior to depositing a load.*

*The actions designated by Y', Z', -Y' and -Z' may be similar for the set of*

*(a) storing a pallet or (b) removing one from the storage bay provided that all the unit storage volumes are similar in dimension and the pallets or totes are the same shape or can be centered on the forks and in the storage volume.*

*As such, these motions may be made inherent in the system by the provision of a sequence command device CD hooked up to initiate the desired sequence (a) or (b) upon arrival of the forks 153 opposite the desired bay. As an illustrative example, assume that it is desired to remove a palletized load from*

*a storage volume located at Row Rx<sub>4</sub>, aisle Rx<sub>6</sub> and 3 tiers up (Z = 3). The predetermined counter is dialed 4,6,3 and the command the command device CB*

*(a) set for (b), removal of a load. The switch 159 is closed, M<sub>1</sub> starts up and the counter receives pulses counting 1/4th locations along Ry until 4 are*

*passed (when the bi-rail system of Fig. 4 is utilized). A switch is thrown opening the circuit with M<sub>1</sub> and closing that with M<sub>2</sub> after 4 counts. The counts*

*then run to 6, down aisle 4 whereupon the conveyor is opposite the X,Y position of the desired volume 153. It is then stopped by a switch opening its circuit*

*of power supply and M<sub>2</sub> starts up and drives the forks up 3 bays. When the counting device controlling M<sub>2</sub> counts out 3 bay locations (in inverse to the con-*

scribed) a switch in the counter opens the circuit with  $M_2$ , closes a circuit with a device braking the upward travel of the forks 153 and also closes a circuit containing the power supply and the command device CD, in particular that part of CD which will control the action of the forks necessary to remove a load from the bay which it is opposite. ( $Y', Z', -Z'$ ). The command device CD then controls the action by counting the rotations of the motors  $M_1$  and  $M_2$  and controlling them to drive the forks to under the pallet, lifting the pallet a small amount, and withdrawing the load sufficiently out into the aisle to permit travel of the forks in the X direction. Upon completion of the action designated as  $-Y'$ , CD shuts off and, at the same time  $M_2$  starts up under control of a predetermined counter which again receives pulses as each bay is passed along  $Rx_4$ . When  $Ry$  has been reached,  $M_1$  is shut down and braked and  $M_2$  drives the conveyor in reverse to the point of origin or to any preset desired location for unloading or further storing of the load on the pallet. The entire sequence of actions in their occurring order and designated by the aforescribed letter designations is:  $Y$  (to  $R=2$ ),  $X$  (to  $x=4$ ),  $Z$  (to  $z=3$ ),  $-Y', Z', -Z'$  (under command of CD),  $-X$  (to  $Y=1$ ),  $-Y$  (to point of origin or any other designated area under control of the predetermined counter computer system).

Several points concerning the command system are noted prior to detailed discussion of the schematic control diagram of Fig. 25. It may be required to store a number of palletized loads from, for example, an unloading conveyor via the unit carrier 22 to a section of unit volumes 153. This may be accomplished in a given order, for example at  $X_1, Y_4$  the Z volumes 1, 2, 3, 4, 5 and 6. The action may be accomplished by using enough counting circuits to count out  $z_1, z_2, z_3, z_4$  etc. following the repetitive sequence  $X_1, Y_4$  or may be accomplished by lock-in switching circuits which will repeat the movements to and from  $X_1, Y_4$  and a stepping switch arrangement which adds a digit to the Z counter each time. The provision of counting devices linked via switching to each other for each of the following motions  $Y, X, Z, -Z, -X$  and  $-Y$  and rapid means for setting said counters, will permit the dispatching of the conveyor unit to any storage volume and its travel therefrom to any other volume or area in the system. In removing the load from its storage position, if a steel tote box or pallet is utilized to hold the load, it may be removed by the provision of an electro magnet movably mounted on the platform 153.

Palletized or boxed material may be rapidly moved to or from a storage area of the type described in one of several manners by the presetting of a predetermined counting device which by the receipt of position locating information, controls the motion on the conveyor. One type of predetermined command device is shown in Fig. 25 as comprising at least three predetermined counters  $PrCx$ ,  $PrCy$ , and  $PrCz$ , each adapted to open and close one or more switches (therein) for controlling the motor controls  $Mx$ ,  $My$  and  $Mz$ . The predetermined counters may comprise mechanical counting mechanisms or electrical counting switches, usually arranged in banks which are actuated by electrical impulses received by one or more position locating devices.

One of several means of operation may be employed. (a) The entire motion of the conveyor and forks may be under command of a presettable predetermined counter or counters which count the rotations of the motors  $Mx$ ,  $My$  and  $Mz$ , the revolutions of which indicate the position of conveyor unit along any row or aisle, and opposite any located storage volume. (b) the conveyor movement to opposite the storage volume may be controlled by the use of predetermined counters which are triggered by electrical impulses from switches closed by physical means locating the position of the column 23 and forks 153 as in Fig. 4 and 5. (c) the predetermined counters may be triggered by photoelectrically operated switches mounted on the conveyor which are closed after the return of a light signal to a photocell as in Figs. 7 and 8. (d) counters  $PrCx$ ,  $PrCy$  and  $PrCz$  may all be triggered by a universal switch 156 protruding from the end of the forks as in Fig. 25 and closing a circuit as it strikes the crossbars 151 and 152 of the storage racking. Once opposite the desired storage volume the forks 153, grab, or platform may be automatically moved to and from the racks 152 with the act of either moving palletized or boxed items thereto setting the load down and storing thereof or removing said palletized or boxed item therefrom. This action may be accomplished in one of several manners. (a) by the use of command device  $PrCx$  which is triggered or started up by  $PrCz$  when it shuts down  $Mz$  and indicates that the desired travel of the forks to be opposite the desired volume 150 has been reached. (b) by the automatic starting up of  $My$  as indicated when a switch closes in  $PrCz$  after it has counted out the proper travel positioning the forks 153 opposite the desired bay, and the driving of the forks towards the racks which are further controlled in the act of moving to or from the storage volume by the use of

limit switches situated on the forks and closing with the engagement of the pallet or racking. (c) by the use of a photoelectric cell 68 and light source 69 situated at the end of forks 153 or platform to scan the product and (or) racking and which controls motion of  $M_x$  and  $M_z$ . (d) by combinations of (a) to (c). The command device (CD) may be any mechanical or electrical device which will open and close circuits with the motor  $M_y$  and  $M_z$  after a specific number of rotations of said motors and in a sequence which will drive said forks in either of two desired sequences (a) the act of  $M_y$  moving the forks 153 in under the load,  $M_z$  driving the forks upward a sufficient degree to lift the load to clear the racks and  $M_y$  reversing the travel of the forks to carry the load to an aisle position whereby the forks and load will clear the racks in their travel parallel thereto and (b) the act of  $M_y$  moving the forks 153, having the load thereon, to said volume,  $M_z$  lowering the forks a degree below which the load pallet engages the top of said racks and comes to rest thereon and  $M_y$  reversing the travel of the forks to remove them empty therefrom to the center of the aisle Rx or a degree sufficient to clear the racks in further travel parallel thereto.

For manual setting of  $Pr_{Cx}$ ,  $Pr_{Cy}$  and  $Pr_{Cz}$  it is preferable to use a dial operated switching device similar to the dial-switch utilized in the conventional telephone, which may be used to cause a series of pulses of current (depending on the number dialed) to actuate a solenoid, setting up the predetermining counter or may be used to close relays in a bank as in a telephone control circuit which may be used as the predetermining counting device. Each signal operated by the position locating device may be used to open one of said relays and the opening of a preset group of said relays may cause opening of a switch in circuit with the particular motor control ( $M_x$ ,  $M_y$ , or  $M_z$ ). Predetermining electrical counting and control devices are known to the art and may be of various designs. For this reason, in the diagram of Fig. 25 I diagrammatically show therein two boxes which are electrically connected to each other and to C.D. for the purpose of starting each to operate in sequence. (i.e. when the counter  $Pr_{Cz}$  runs out and the conveyor assembly is opposite the X, Y location of the desired bay, it closes a switch therein which closes a circuit containing  $Pr_{Cz}$  and a photoreceptor 31 <sup>911 X</sup>).

which commands thereby starting up Pr Cz, which sends travel of 153 when Pr Cz runs out. At the instant the forks 153 are opposite the desired bay it opens a switch in circuit with the 152 controls and braking means and simultaneously closes a circuit with C.D. which initiates the predetermined actions.

The command device is shown in FIG. 25 as being divided into two sections. C.D. and C.D.'s. C.D. is used to designate that part of the command device which controls the automatic action of the forks 153 traveling empty from the aisle opposite the bay 150, to said bay, picking up and removing the palletized load therefrom. C.D.'s is that part of the command device which controls the automatic action of the forks 153 carrying a load from the aisle position (opposite the storage volume) to said volume, setting down the load and returning empty again to the aisle position. Either C.D. or C.D.'s is preset or thrown into the circuit with the predetermined counter PrCz at the dial switch 164 after PrCz has been dialed by the use of said dial switch or by push button switches 165, closing a circuit and actuating a solenoid in C.D. to close a switch looking into the circuit with PrCz.

The letters PrC'y, PrC'x and PrC'z designate predetermined counting devices which are used to control the movements -Z, -X, and -Y of the conveyor assembly out of the storage area to dispose of or pick-up another load. PrC'x, PrC'y and PrC'z may be set by dialing 164 or may be of such a design that they automatically become set by counting up with the uncounting of PrCz, PrC'y and PrC'z.

In FIG. 25, the switch 155 which is located on the end of fork 153 is used to count the number of storage bays 150 travelled in the Z direction by closing a circuit with the counter PrCz everytime the switch arm 156 strikes a horizontal crossbar 162 or shelf. If switch 155 is a universal switch which is normally open and closable everytime the forks pass a storage unit volume 150 and arm 156 strikes either 151 or 152, then 155 may be used for so to locate the preset or desired storage unit volume. In this arrangement, 156 would be connected to the predetermined counters thru PrCz, permitting the aforescribed station keeping actions. The switch 159 may be eliminated if the forks make to always travel opposite the racking so that 156 will be deflected with the X, Y or Z motion thereof. If the monorail system is utilized, this is a matter of positioning the trackway so that the forks, when retracted, will just clear the racking. If the bi-rail conveyor is utilized with the switch 155, the aisle-stopped position of the carriage 22' would be such that the forks 153 would just clear the racking so that the switch arm 156 is deflected with movement of the forks thereon.

*crosssectioned*

Fig. 26 is a partially crosssectioned, partial side view of a fork or plate 153 showing a compression or limit switch 161 mounted in a cavity 162 in the top of the forks to project upward therefrom and be closed in the act of the forks being moved to the bottom of a pallet 154 when a pallet or load is placed thereon. Said switch may be used in a system (a) not having a command device to stop the Z' travel of the forks a short time after it 161 is compressed and start up by initiating the Y' motion of removing the forks with the load thereon or (b) in a system having command devices C.D.1 and C.D.2 to indicate whether the forks are empty or a load is thereon. If a load is thereon when Prcz is set by dialing 164 then the computer C.D.1 would be locked in with Prcz and the storing sequence would occur after the counting out of Prcz. The numeral 163 refers to a compression operated switch projecting from the end of 153 or possibly from the end of 156 which may be used as a safety device. The switch 163 may be used for example to indicate an item is already located in a particular unit volume in the event that the operator makes a mistake and dials the work volume in which to store. 163 may be connected in circuit with a solenoid actuating a switch shutting down the motors in the system.

Fig. 27 is a partial diagrammatic view of a predetermining counting system utilizing a photoelectric cell 68 and light source 69 to detect station or bay locations. A small reflector 70 is positioned at the same relative attitude respective to each bay on either the vertical 151 or horizontal 152 cross racking facing the figs Rx and Ry so that the beam from the light source 69 may be reflected thereby back to 68 and close a switch in photoelectric control 163 signaling the predetermining counters which have been preset by dial switch 164. The photo-cell 68 and light source 69 are preferably mounted in a single casing at the side of column 23 as shown or within 23 between the forks and positioned so that the

light beam may project against the face of the racking 151. 68 and 69 are preferably mounted on forks 153 to move up and down therewith if 23 is fixed vertically.

Fig. 28 is a diagram of the photoelectric control circuit which amplifies the signal in the phototube reflected off 70 from the light sources 60, and the relay 164 actuated thereby which is electrically connected to the means actuating the predetermining counter every time it, 164, is actuated.

Fig. 29 is a partially cross-sectional view showing means setting the predetermined counter PRC from a location which is remote from the individual work carrier column 23. The numeral 169 refers to a wall or upright positioned below said overhead trackway to be adjacent to said vehicle work supporting column 23 when the latter is at a starting position or parking area awaiting dialed command signals. Electrical brushes 166 sweep over the surface of contacts 167 projecting from 169 making electrical contact therewith while the conveyor is parked or at a standstill thereat. The dial switch 164 may be located at a remote distance from 169 convenient to the operator's reach. Via the brushes 166 and contact bars 167, it becomes electrically connected with PRC which is in the conveyor assembly as shown. As such, 164 may be used to preset PRC by acting as an intermittent switch in circuit therewith and, for example, actuating a solenoid or solenoid therein to set-up PRC, PRCy, PRCz.

The numeral 70a (Fig. 28) refers to a second reflective marker positioned adjacent to the marker 70. It is utilized to effect more precise stopping of any moving part of this invention which is controlled by the photoelectric cell 68 and light source as follows. The reflection of the beam from 69 from 70 thru the relay 164' sends a pulse or current circuit to a device such as a solenoid which either slows or brakes motor Mx (or whatever motor is driving the unit past 70) a sufficient degree to be precisely stopped at a desired position upon the passing of 70a. The same effect may be attained by utilizing the reflector 70 just before the one desired at which to stop the unit to initiate action slowing down the driving motor.

Both the monorail and biaxial conveyor units are shown in Fig. 24 for the purposes of illustration. The forks 153 of the monorail unit (foreground Fig. 24) are shown drivable up and down by a chain 157 and sprocket driven by Mx, and drivable in and out (laterally respective to 23) on a mount by My which rotates screw 42' which longitudinally moves a collar 43' secured to the mount 153'. The numeral 154' of Fig. 24 refers to a tote box in a bay with a pallet shaped bottom permitting it to be picked up by forks 153.

Jerome D. Leshukson

after it is secure at the station. The jig 100, since its external dimensions permit ease of conveyance and ease of handling, transferring, positioning, clamping, removing, etc., is thus a means to a very flexible system of automatic production whereby a variety of different products may be handled automatically by simple adjustments or changes of the station machine tools. Means handling the unit 100 (towed from each machine) may remain fixed and need not be altered for a variety of products.

Fig. 18 shows an elaborate conveyor unit 100 design having a computer 47 mounted in a base compartment thereof below the clamping section. The computer 47 may be a timed sequence-command device and is utilized to both select stations and command operations of the machine tool by making electrical connection with the machine base 71' or back stop "S" as shown in Fig. 14. Contacts 84 and 87 which mate when the unit 100 is secured at the machine electrically couple the two together.

Station selection is attained by the use of reflective strips 10 on the conveyor guide or wall 108 which are scanned by a photoelectric cell 68 mounted on the wall 101a of the unit 100 and positioned to scan 108. When a predetermined station has been identified by computer 47, a solenoid actuated ram 103 powered by a self contained battery or one mounted in 47, projects its ram operated face plate 104 against the side of 108 forcing the unit 100 off conveyor 107 onto roller conveyor 110 leading to platform 71' under the operating section of the machine tool MT. When the conveyor unit 100 reaches the bed of the machine it strikes the back wall or stop "S" thereof. It is further positioned after closing the inward movement of the side clamps 73 acting against the side walls of 100 and in doing so it closes the limit switch 115 mounted in the base 71 which is in circuit with the machine situated clamps 73. Said conveyor unit 100 is further positioned by the inward or lateral movement of the side clamps 73 and by the use of end clamps (shown as the cam shaped clamps 112 of Fig. 19 which project against the rear face 101a of 100 and force the cubicle against S. Clamps 112 are mounted on laterally extending shaft 112' which is rotated the required degree by the use of spur gear 114 also mounted on 112' and spur 114' which is slidably mounted under conveyor 109 and (or) 71' and moved longitudinally by a solenoid actuated

Upon the completion of machining or other work on work in process held in 100, the clamps 73 and 112 are automatically returned to their release or unclamping position by limit switches controlling their solenoids which are actuated by the machine motion in the act of withdrawing from the work or by the computer commanding the sequential operation of the tool, if such is used. Said action is followed by the longitudinal outward movement of ram 111 (solenoid or hydraulically actuated) which pushes the unit 100 away from the machine and back onto conveyor 107. While not shown, this action of pushing or moving 100 back on the conveyor would be delayed in the event that there is another such unit carrier on said conveyor opposite said machine. A photocell relay electrically connected to open the circuit of the solenoid actuating 111 when another 100 unit is theropposite, may suffice. Also not shown but essential to smooth operation where the cycle time at each machine varies, and each unit 100 contains the same work in process, are means before each station to stop the conveyor 107 should a unit 100 approach said work station while work is held thereat. Said means may comprise limit relays in circuit with the 107 conveyor driving motor and opening said circuit when said switch or photocell detects the presence of 100. The numerals MC2 and MC3 refer to servo motors or solenoids driving the work clamps C2 and C3, for example 102 and 105, thru 8H<sub>2</sub> (a spur or worm gear train between MC2 and C2) and the numeral 106 to a door in the wall 101B opposite command device 42 permitting quick removal and replacement of a command recording therein.

Fig. 19 shows a simpler design of the work carrier and the associated conveyor detection apparatus. A photoelectric cell 6 combined with a photoelectric control unit actuating a relay is mounted on the conveyor rail or wall 108 to scan across the conveyor. The cell is provided with its own light source 69 and detects the presence of 100 or 107 by reflection of light thereoff, thereby actuating a relay closing a switch in the circuit with solenoid 103 actuating a ram (not shown) which pushes 100 off 107 and on to 71'. Said relay is designed so that it will actuate 103' only after the photocell 68 has been twice actuated so that the unit 100 may pass back onto 107 after the station ram 111 has ejected it and will not be disturbed thereon by 103'. An alternative is to reflect light from 69 off a reflecting strip 70 situated on the side of 101a which by use of a delay between the energizing of 68 and the actuation of 103' does not

again cross the path of the beam 69 after the unit has been ejected from the machine.

The numeral 113 refers to a reference area on the surface of work W preferably machined or otherwise formed thereon utilized where needed as a reference surface for a cutting tool or probe guiding the motion of a tool. If reference surfaces 113 are formed or machined on more than one surface of W so as to define the position of W in the X, Y and Z planes, then the work holder unit 100 need only be used as a conveying medium for W and the work therein may be located at the machine. The numeral 113' refers to a reference hold in W, one or more of which may be used for positioning, referencing and (or) handling purposes. The numeral 109' refers to end of the guides 109 (leading to the bed 71' of the station machine 11) which are beveled inward to guide the work carrier 100 to the bed 71' in the event that it over or under rides the station position on 107.

912.

Predetermined Command Computer

33 -

The aforescribed production operations may be automatically accomplished in one of several manners. The entire operation including motion of the work in the X, Y and Z directions and any needed tool or tool bed motions may be controlled in its entirety thru a series of switches in various circuits with a power supply and the motors driving said work clamping device work and tool in the required directions respective to each other, said switches accomplishing this end by being used to open and close in the correct sequence for the proper time duration to accomplish the required results. This may be accomplished, by providing a sequential array of switches and circuits with adjustable preset time delays in each. A more versatile predetermined command system is one utilizing a recording medium for opening and closing the various operating circuits in a desired sequence and for a desired period of time. Magnetic recording means have been used to open and close a series of circuits in sequence and involve merely the recognition of a signal by a magnetic pick-up or head riding on a continuously moving tape or wire, said signal being amplified and utilized, for example, to fire a thyratron tube and actuate a relay closing or opening a switch. A more preferable arrangement from the point of simplicity and interchangeability is to employ a punched card or tape driven at a constant speed in contact with a series of arms or feeler elements riding thereover.

For particular production problems, a more practical approach (than that of having the entire sequence of production operations solely under the control of a command computer), is to command parts of the cycle when said work conveyor is there opposite and combine said action with reference or locating points along the production line with a means for detecting said locations, to either supplement or initiate said commanded motions. In this way, tendencies for errors to accumulate in the mechanical-electrical system due to free play, slippage, etc., are minimised or eliminated. Control may be effected by (a) starting the operating and command recording to run only when needed, for example, at the static or machines, by opening and closing its own driving motor circuit at each station by using limit switches motivated by motion of the work conveyor respective to the conveyor system; (b) permitting said recording to run continually and providing sufficient dwell or extended periods in or between each commanded action to permit the completion of automatic actions or sequence of actions necessary to complete the operation. Several of said automatic actions permitting the

34 -

may be, have been described. They may for example, the limit switch controlled action of stopping and aligning the work or work holding unit at the machine tool base 71'; automatic clamping, grabbing, holding or moving of the work or work holder, at the machine; automatic travel of the powered work conveyor unit from station to station; automatic braking and prepositioning of said work conveyor unit; automatic picking up and dropping or ejection of the work from the work conveyor platform or clamps; automatic removal of machining wastes at the machine or from the work conveyor unit; automatic inspection operations including probing actions at the machine which are either preset or commanded as described and provided with feedback for tool corrective measures (said probing action may be actuated by a limit switch triggered by the action of the tool returning to a neutral position following its operation on the work); automatic movement of the work holding platform 35 from one side of the conveyor to the other, etc. The production cycle would thus consist of a series of commanded actions directing movement of the work to the stations, machines and possibly movement of the machine tool (if it does not have its own command system), intermixed with a series of actions which are either commanded or automatic and automatically initiated by the motion of the work conveyor unit respective to switches or photoelectric switching devices positioned in the system.

Fig. 20 is a diagrammatic drawing of the punch card operated sequence command computer and Fig. 21 a wiring diagram of the computer and electrical devices which may be controlled thereby. The command recording, representing the time durations of the rotation of the various motors of the system or the opening or closing of solenoid actuated switches, is shown as a series of cutouts in the punched card 119. Said card is driven at a constant speed between frictional or toothed rollers 121 and 121' rotated by motor 125. Feeler arms 122 ride over the card in its longitudinal travel, in and out of the recesses or cutouts <sup>124 1/4</sup> therein, and are pivotally mounted to open and close a series of switches 122 which completes or breaks circuits with motors M<sub>2</sub>, M<sub>3</sub>, M<sub>4</sub>, etc. (associated with the work conveying units 22 or 100) and motors M<sub>1</sub>, M<sub>1x</sub>, M<sub>1y</sub>, M<sub>1z</sub>, M<sub>1bc</sub>, etc. associated with the machine tool, tool bed, clamps, etc. If the speed of travel of the card 119 relative to the feeler elements 122 is constant and accurately controlled, the length of the slots or cutouts 124 in the card 119 will determine the time of operation of each motor and hence

the degree of tool work and stopping characteristics of the tool, inspection device, etc. If the starting cutouts 124, distances moved in the x, y and z planes under command, may be maintained to a specific accuracy. If this accuracy will suffice for the entire operation, the command system per se may be used. Due to free play, and the various other errors into the system and command computer, most manufacturing operations on work in process utilizing the components of this invention will require the limit switches, photoelectric devices, etc. for locating purposes and to initiate other automatic actions.

The command computer of Fig. 20, designated by the numeral 47, is mounted in a casing comprising end walls 116 a and 116b. A powered roller 121 is supported in bearing by the sidewalls 116 and is rotationally mounted therebetween below idler roller 121' in a manner permitting a card 119 or tape to be driven therebetween. The numeral 125 refers to a motor driving roller 121 thru bevel or worm gears 126 and the numeral 125' to a housing in which a motor control is mounted for accurately controlling the speed of motor 125 and keeping it at a constant value. There are a number of such controls available to the art and it is therefore not considered necessary to go into the details thereof. The card 119 is placed thru the opening or slot 118' in the wall 118, is driven thru rollers 121 and 121', is guided laterally by the walls 116 or projections thereof and supported in its longitudinal travel thru the computer on base 119.

Fig. 21 is a schematic electrical diagram of the command computer of Fig. 20 and the various electrical components of the system. The feeler of switch arm elements 122 controlling the switch S<sub>Mx</sub> which is in series with the motor M<sub>x</sub> and the power supply are referred to by the letter F and the designation for the particular rider arms are F<sub>Mx</sub>, F<sub>My</sub>, F<sub>Mz</sub>, etc. The switches they control are referred to as S<sub>Mx</sub>, S<sub>My</sub>, S<sub>Mz</sub>, etc and are in series circuit with a power supply thru the brush elements 27 and the motor controls (including braking devices) for motors M<sub>x</sub>, M<sub>y</sub>, M<sub>z</sub>, etc. Although only five switches are illustrated, others are inferred by the use of arrowheads on the leads to particular switches, solenoids, motors associated with the conveyor, trackway, station machines, etc. The switch 59 is shown connected to M<sub>x</sub> and is such a design that it may bypass

3.2 forming, molding, assembly, finishing, inspecting machines available to a variety of different products by the use of

*63*  
Site for a period which is greater than required to drive conveyor unit column 23 or crossbridge 25 to the station, then it will be guaranteed to reach the station and may be stopped precisely at the station by either the pin actuated switch 59 or the photoelectric cell arrangement of Figs. 7 or 8.

The numeral 159 refers to a starting switch for turning motor 125 on and off. The numeral 86 refers to the contact coupling arrangement between the conveyor work holding platform 138 or unit 100 and the machine tool which has been described and illustrated in Figs. 14 and 15 and is used to convey electrical command signals from the computer when mounted in the conveyor unit to the machine or machine tool servos, MT<sub>x</sub>, MT<sub>y</sub>, MT<sub>z</sub>, MTBC, etc. The letters MTBC refer to servos or motors driving clamps or holding devices at the base of the machine or machine tools. Also shown in Fig. 21 are inspection or prepositioning probes designated as I<sub>x</sub>, I<sub>y</sub> and I<sub>z</sub>, etc., with their associated probing heads, IP<sub>x</sub>, IP<sub>y</sub>, etc. Each of said probes is electrically connected to an affiliated computing devices IC<sub>x</sub>, IC<sub>y</sub>, IC<sub>z</sub>, etc. which receive signals from the computer 47 indicating the desired motion of their probes for an acceptable product. The probe computers IC<sub>x</sub>, IC<sub>y</sub>, IC<sub>z</sub> thru one of various electrical means, record the time durations of the signal from the computer 47 and thru the medium of feedback (indicated by the double arrow designation to I<sub>x</sub>, I<sub>y</sub>, I<sub>z</sub>, etc.) control the motion of MT<sub>x</sub>, MT<sub>y</sub> and MT<sub>z</sub>. A sufficient dwell in the recording on 119 between the next command signal may be provided to account for the operations of the machine tool under command of the feedback-probe-computer arrangement to account for more than the longest expected cycle or, this variable may be allowed to run to completion while the computer 47 shuts down. Shutting down of computer 47 may be accomplished by a self excited switch 159' which is urged to close upon the completion of the signals to the command computers IC<sub>x</sub>, IC<sub>y</sub> and IC<sub>z</sub> which thereby start up 47 again by actuating 159'. It is also operated so that it may be urged closed by a signal from said computers.

Fig. 21 shows several components which may duplicate functions. These are illustrated in the single diagram to show that they may be utilized at any point throughout the system and to show their position in the circuit. It is noted that a number of the components of Fig. 21 may be omitted for specific production operations or the circuit may be made more complex with additional stops, servos, probes, positioning, locating, feeding and clamping devices, devices associated with operations other than machining such as assembly, forming, molding, finishing, inspecting machines which now become applicable to a variety of different products by the use of

7HX  
3  
and the  
of the aforesaid devices, a highly versatile system described for  
the handling of work in process.

numerically  
controlled

The computer 47 may be of various designs (the function of which are not necessarily based on the time duration of a signal such as the device of Figs. 20 and 21) to control the various operating and servo devices associated with motions of the work and machines. A computer utilizing electrical counting devices to count the revolutions, or fractions thereof, of said conveyor and machine tool driving motors from a base or zeroed position is conceived as a suitable application for the command functions. Counting circuits consisting of banks of presetable relay switches have been used to direct the motions of devices powered by servo motors, etc. One conceived device or system as applicable to the components of this invention which would permit a very flexible degree of manufacture and could be easily changed in regards to command sequence would comprise (a) signal input section which would set up the desired sequential order of command signals from a recording by presetting (b) banks of counting relays which, at the proper instant in the cycle, would count out the revolutions of each of said servo devices (M<sub>x</sub>, M<sub>y</sub>, M<sub>z</sub>, M<sub>xz</sub>, etc.), open or close a switch when the preset count had been reached, thereby stopping or braking said motors. In this manner, the degree of travel of the tool or work, which is a function of the rotation of its driving motor could be preset and predetermined to perform a specific operation on any work which is referenced respective thereto. The signal input section could, for example, be the computer of Fig. 20 with nine of the switches 123 being arranged to represent the digits 1 to 9 and one representing zero, and electrically connected to close the desired number of relays in a bank. If holding relays are utilized, the digits 1-10, 10-100, 100-1000, 1000-10,000 etc. may be simulated or set up in different banks to count out, for example, a four digit number of revolutions of the particular servo. The feeler elements 122 falling in and out of slots in the card or tape 119 could by the use of signals generated with the closing and opening of the switches 123 open a circuit with a bank of holdable relays and by current pulses from the switches representing the digits closing set up or hold a specific number of said relays. If, for example, a current pulse could be generated by rotation of the shaft of the particular servo motor with every revolution thereof, and every revolution moves the tool .001 inches, then the desired motion of the tool may be controlled by

37<sup>th</sup>

Coopch

arranging the bank of relays, then a circuit with the particular servo motor and its source of power or close a circuit with a braking device which is calibrated to brake said motor a desired period after being actuated, said action taking place after the last of the preset number of relays have been opened. For example, if it is desired to move the tool .008 inches in the X direction, the bank of relays controlling the X motion of the tool from a zeroed or other position known to the command system would be set up by the first 8 of the switches 123 falling into slots 124, closing and by providing means electrically connecting each of said switches 123 with a corresponding relay in the bank, the first eight of the bank relays may be closed. The bank circuit, termed a register, can store information (numbers) set into them for indefinite periods, and as stated, may be used to count by decades in the decimal system. By shunting the signal driving thru this bank, said action may be so initiated upon the completion of the count if the relay is such that its opening with (a) either open the circuit with MTx or close a circuit with the device braking MTx. Upon the receipt of 8 pulses indicating 8 revolutions of MTx the circuit with MTx is thereby opened and (or) the braking device is energized.

J.H.L.

of the aforescribed devices to the highly versatile systems described for product handling.

The computer 47 may be of various designs other than that of utilizing the time duration of a signal to open and close circuits with electrical servos. For example, another method applicable to controlling the servos of this invention utilizes a computer and punched card or tape to relay information in the form of signals (representing numbers in the decimal system) to banks of counting relays, each bank representing a decimal position in the decimal system which counts a revolution or groups of 10,100,1000 etc. of said revolutions of the particular servo motor or driving mechanism. As such, said counting relay circuits may be used to control the x,y,z and rotational motions of the tools or work respective to the tools. For example, assume that the motor  $M_x$  is to be directed to drive the cutting tool of an automatic milling machine a distance of 2.357 inches from a zeroed or at-rest position, in the x direction. Assume also that every revolution of the motor controlled by  $M_x$  is such that motion of the tool will be .001 inches in the x direction with the completion of said motor revolution. To attain this distance we utilize a relay counting system having at least four banks of relays with ten relays in each bank. The relay banks are set up by the computer arms 122 riding in and out of predetermined slots which look the first and in the first bank closed (to represent the digit 2 or the 2 inches of the number 2.357), the 3rd relay in the second bank, the 5th relay in the third bank and the 7th relay in the fourth bank, thus setting up the number 2.357 in the relay banks. The relays are so interconnected that when the motor  $M_x$  has rotated 2000 times the second relay in the first bank will have been opened thereby throwing the counting circuit into the second bank, each of said master relays therein counting 100 revolutions and with each 100 opening the first, second and third relay therein respectively; upon the opening of the third relay of the second bank closing the circuit with the fourth bank, etc. until all four banks have been gone thru and the number 2.357 has been counted. When the third bank of relays is operating, which counts one hundredths of an inch of motion of the tool or tens of revolutions, a switch is automatically thrown which is in circuit with means slowing down the speed of the motor driving the tool to a fraction of its normal speed, thereby

~~to be stopped more precisely at its desired travel distance as the fourth bank of switches runs out. The employment of banks of said counting switches to control the revolutionary travel of a servo motor is known to the art and may not only utilize electro mechanical relays but also electronic counting circuits.~~

~~The following example is presented to illustrate a possible sequence of operation of the components of Fig. 21. The card or tape 119 driven by motor 125 starts motion relative to the feeler elements 122 (FM<sub>x</sub>, FM<sub>y</sub>, FM<sub>z</sub>, -FM<sub>x</sub>, -FM<sub>y</sub>, etc. not shown) by representing circuits associated with the computer 47 for commanding reversing the motors M<sub>x</sub> and M<sub>y</sub>, etc. when needed. Motor M<sub>x</sub> is started up and travels along the overhead track to the first station. If it is desired to stop the conveyor unit at the first station, the switch 59 may be~~

~~employed and may be actuated to brake the carriage 22 or stop the motor as in Fig. 5. Assuming that it is desired to stop at a station, the feeler element FM<sub>x</sub>' is employed. FM<sub>x</sub>' rides into a hole 124 in the card 119 closing switch SM<sub>x</sub>' which closes a circuit with the power supply and motor M<sub>x</sub> the switch 59 which is normally closed. With the closing of SM<sub>x</sub>', FM<sub>x</sub> rides out of a hole in the card, SM<sub>x</sub> opens, thereby opening its circuit with M<sub>x</sub> and the power supply and permitting M<sub>x</sub> to be stopped when switch 59 is opened by the station locator pin 62 or~~

~~by the photo-electric relay of Figs. 7 and 8. Switch 59 may be a dual switch which actuates solenoid 65 at the same time it opens the circuit with M<sub>x</sub>. Said solenoid 65 may be used to brake the motor M<sub>x</sub> or stop the conveyor unit precisely at the station as in Fig. 6. The actuation of 59 at the station may also close a circuit with M<sub>y</sub> and the power supply to drive the platform 75 towards the machine~~

~~bed 71 until it (S<sub>2</sub>) strikes the stop S or end of the machine bed, thereby opening platform end switch 89 upon contact with S and stopping M<sub>y</sub>. Or, a circuit comprising a switch SM<sub>y</sub> actuated to close by a feeler arm FM<sub>y</sub> may permit M<sub>y</sub> to drive the platform to said machine bed 71 which is either stopped thereat by FM<sub>y</sub> riding out of its card slot 124 or by 89' in a manner similar to that by which 59 stopped M<sub>x</sub>. Actuation of the machine tool mechanism may be initiated by limit switches SM closed by the motion of the platform towards the machine as in~~

~~Figs. 9 to 11, or by signals from computer 47 thru the electrical coupling of Fig. 14. When the elements FM<sub>x</sub>, FM<sub>y</sub>, FM<sub>z</sub>, etc. drop into cutouts 124 in the card 119, the complete circuits thru the coupling means of Fig. 14 with a power supply and M<sub>x</sub>, M<sub>y</sub>, M<sub>z</sub>, etc. and may be utilized to command the actions of the tool respectively to the work. Thus 47 may be used to control tool motion, feed, speed, etc.~~

arrangement may variations on this arrangement be utilized (such as the placing of easily adjusted or changeable command devices at each tool which are started by limit switches actuated by motion of the conveyor or by the command device 47 at the conveyor unit).

When the machine tool MT has completed its operation on the work, the motion of the tool in withdrawing from the work may be utilized to effect release of the work from the machine tool clamps MTBC, etc. or this action may be accomplished by signals from 47 at the proper time. This action also initiates withdrawal of the conveyor unit from the machine by the starting of M<sub>1</sub> in reverse to effect said withdrawal to the aisle station position. Again, the withdrawal may be attained under command from 47. When the work platform has returned to its aisle position, M<sub>1</sub> stops either automatically by the use of a limit switch or under command of 47. The stopping of M<sub>1</sub> may be utilized to start up M<sub>2</sub> to drive the conveyor unit along to the next station, etc. While the schematic drawing (fig. 21) is not complete for these setups (such as just described) involving the use of limit switches (at the platform or machine tool actuated by the motion of either relative to each other or to itself) to start and stop motions of the conveyor unit, work W, work platform 36 or tool or for the purposes of initiating and ending other actions such as work release, working positioning, work turning, clamping, or other machine motions and operations, the electrical diagram would merely show a repetition or an elaboration of the switch (59) and computer control means used to control M<sub>2</sub> and described above.

Summarizing the possible methods of automatic control as applicable to the automatic manufacturing components heretofore described, (a) the conveyor units described may be operated and controlled solely by the use of position detecting devices such as limit switches, photoelectrically operated switches, etc., (b) the entire sequence may be commanded by the computer such as 47, (c) the operation may be commanded in part by a computer such as 47 mounted on each conveyor unit, said computer continuously running and supplemented by actions actuated by position detection switching devices, (d) the operation may be commanded in part by a computer which runs intermittently, is stopped and started and supplemented by position detecting switching devices such as 59, 68, 69, SW, SW', etc., (e) the conveyor units described may be automatically moved from station, stopped and directed to the machines by the position detecting means described, clamped in a prepositioned attitude respective to the machine and operated on thereat under command of a station situated computer which is easily and rapidly changed as is 47.

- 41 -

3  
applications for those production applications requiring such a number of individual pre-determined command signals and where said signals would not all easily be put on a card as a series of cutouts, etc. the use of a tape is preferred. Figs. 21 and 22 show magazine loading tape arrangements for a punched or cutout tape and a magnetic tape respectively. These will save setup time and will be especially useful where there are a variety of products in production on the same line and the demand for each varies with time (viz: one or two parts may be automatically made without an expensive setup in the proposed systems, and the sequence command signals may be varied for each product by merely removing and replacing a magazine).

Fig. 22 shows a punched tape magazine and mounting. The magazine is a container having parallel faces 130 spaced apart by a rim wall 131 extending thereabouts, save for an opening 132 exposing the punched tape 133 which winds around one end spool 134 to a second end spool 135 situated within the container. The tape thus extends preferably about the open face said of the container. The end spools 134 and 135 are rotationally mounted on bushing 136 or pins which are supported in bearing between the parallel faces 130 of the container. A series of rod like fingers 122 riding on the surface of the tape 133, each extend from a switch 123 mounted on a support 137 and are adjusted to actuate said switches (i.e., electrically open or close them) whenever the finger ends drop into or are forced out of a cutout in said tape. Each of said switches is connected in series circuit with an electrical device associated with the production system and a power supply. The container 130 is easily mounted and removed from a base 137 so that the shaped end of the shaft 138 of a constant velocity motor 139 projects thru either of the bushings 136 on which end spools 134 and 135 are mounted and may turn said bushing with the rotation of said motor. The numeral 140 refers to a cylindrical roller (or rollers) mounted on a vertical shaft extending from base 137 which may be utilized to facilitate passage of tape 133 and to back or reinforce it in the areas where the feeler elements or fingers 122 ride thereover. If the roller is utilized, the cutout section 132 of the container must, of necessity, be large enough to permit its free rotation. An alternative is to rotationally fasten the roller between the parallel walls of the casing opposite or adjacent to the opening 132 as shown. The numeral 139' refers to a second servo motor which may be also mounted on 137 to reverse the direction of travel of 133 for rewinding. The two motors 139 and 139' may be replaced by a single motor or a solenoid adapted to move the tape 133 a brief interval each time it is actuated.

- 42 -

Fig. 23 is an isometric partial view of a modified design of the magazine of FIG. 22. The aforescribed punched tape 133 has been replaced by a tape 133' with a magnetic recording thorson, which winds from one reel 138 mounted within the casing to within another reel 135 also mounted therin. The magnetic tape 133' is thus totally enclosed save for an opening 132, which extends across one edge from the surface 130 to 130'. As such, the conventional magnetic pick-up mechanism comprising, in part the drum 144 may be passed thru the opening 132 in the act of mounting the magazine on the base 137 which serves as a backing and positioning device for the magnetic tape and is part of the pick-up mechanism working with the pick-up head 142 which is positioned there opposite. As the pickup head 142 must either make contact with or be positioned just off the surface of the tape 142, it (142) is mounted on a projecting base 143 which is slidable mounted on guides 143' extending from base 137 and is spring mounted via compression spring 146 (engaging 143) to load 142 against the tape or to a position just off the tape. In mounting the magazine 133' to be passed between 144 and 142 without injury. The base 137 mounted stops 146 and then utilized to clamp the magazine casing in place. The shaft 138 of the servo motor or servo device 139 is then engaged with either or both of the reel bushings 138' or may be spring loaded axially to automatically engage said bushings when the magazine is slipped into place. This may be accomplished also by merely mounting the magazine so that it is over and engaged by the projecting ends of engaging and driving mechanism, the design presented only to illustrate the fact that a servo device or motor engages the shaft of the reels. 211